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Library of anomalous $\tau\tau\gamma$ couplings for $\tau^+\tau^-(n\gamma)$
Monte Carlo programs

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ABSTRACT

We briefly describe a library that may be used with any $e^+e^- \rightarrow \tau^+\tau^-(n\gamma)$ Monte Carlo program to account for the effects of anomalous $\tau\tau\gamma$ couplings. The implementation of this library in KORALZ version 4.04 is discussed.

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1 Introduction

Radiative τ pair production is of great interest, as it is sensitive to anomalous electromagnetic couplings of the τ . With the sensitivity afforded by the LEP experiments, this provides an opportunity to search for new physics phenomena [1–4]. Any meaningful interpretation of the experimental data requires a Monte Carlo simulation in which Standard Model predictions may be augmented by the contributions from possible anomalous couplings.

Since the LEP collaborations are entering their final years of operation it is a good time to document the programs that were actually used in data analyses. In this paper we describe a library that has been used to calculate anomalous contributions to $\tau\tau\gamma$ couplings [2]. The library is based on the work described in [4] and can be used with any $e^+e^- \rightarrow \tau^+\tau^-(n\gamma)$ Monte Carlo program and, after minor adaptation, with $pp \rightarrow Z/\gamma + \dots$; $Z/\gamma \rightarrow \tau^+\tau^-(n\gamma)$ or $ep \rightarrow Z/\gamma + \dots$; $Z/\gamma \rightarrow \tau^+\tau^-(n\gamma)$ programs as well.

In the present paper, we will discuss the interface of our library to KORALZ version 4.04, which is described in detail in [5, 6]. The fortran code of the library is archived together with KORALZ [6], in the same tree of directories. Let us note that in the future, KORALZ will be replaced by a new program, KK2f [7], which is based on a more powerful exponentiation at the spin amplitude level; implementation of our library will be straightforward for that program as well.

2 Calculation of anomalous couplings

To evaluate the effects of anomalous electromagnetic couplings on radiative τ pair production, a tree-level calculation of the squared matrix element for the process $e^+e^- \rightarrow \tau^+\tau^-\gamma$ has been carried out [4], including contributions from the anomalous magnetic dipole moment at $q^2 = 0$, $F_2(0)$, and the electric dipole moment $F_3(0)$. This calculation is included in our library. When activated, it uses the 4-momenta of the leptons and the photon generated by the host program to compute a weight, w , for each event according to

$$w = \frac{|\mathcal{M}_{\text{ano}}|^2}{|\mathcal{M}_{\text{SM}}|^2}. \quad (1)$$

\mathcal{M}_{ano} is the matrix element for $F_2(0) \neq 0$ and/or $F_3(0) \neq 0$, and \mathcal{M}_{SM} is the matrix element for $F_2(0) = F_3(0) = 0$.

As this calculation is performed at $\mathcal{O}(\alpha)$, the case of multiple bremsstrahlung requires special treatment. In this case, a reduction procedure is first applied in which all photons, except the one with the greatest momentum transverse to a lepton, or p_T , are incorporated into the 4-momenta of effective initial- or final-state leptons. The 4-momenta of the photon with greatest p_T and the effective leptons are then used to compute the weight. Cross-checks of the calculation against an independent and slightly simplified analytical calculation [8] as well as checks of the validity of the reduction procedure are described in [9]. The results of the calculation have been used in the measurement of anomalous electromagnetic moments of the τ described in [2].

3 Flags to control anomalous couplings in KORALZ

In KORALZ version 4.04, the calculation in our library is activated by setting the card `IFKALIN=2`. This is transmitted from the main program via the KORALZ input parameter `NPAR(15)`. Additional input parameters are set in the routine `kzphynew(XPAR,NPAR)`, although there are currently no connections to the KORALZ matrix input parameters `XPAR` and `NPAR`. Table 1 summarizes the functions of these input parameters.

Parameter	Description	Default
IFL1	Compute weights for $F_2(0)$ if IFL1 = 1	1
IFL2	Compute weights for $F_3(0)$ if IFL2 = 1	0
ISFL	For ISFL = -1, compute <i>only</i> terms with anomalous contributions. For ISFL = 0, include all terms (anomalous, Standard Model, all interference). For ISFL = 1, use the approximation of ref. [8]	0
IREC_SOFT	Generate <i>only</i> events with photon(s) if IREC_SOFT = 1	0
EMINACT	Minimum sum of all photon energies required to calculate anomalous weights	17 GeV
EMAXACT	Maximum sum of all photon energies allowed to calculate anomalous weights	1000 GeV
PTACT	Minimum sum of all photon momenta transverse to the beam direction required to calculate anomalous weights	2 GeV

Table 1: Input parameters to control the calculation of weights for anomalous electromagnetic moments.

In order to provide the user with enough information to retrieve w for a given event for any $F_2(0)$ or $F_3(0)$, we take advantage of the fact that, for each event, one may write w as a quadratic function of the anomalous couplings:

$$w = \alpha F_2^2(0) + \beta F_2(0) + \gamma F_3^2(0) + \delta F_3(0) + \epsilon . \quad (2)$$

When the calculation of w is completed, the 5 weight parameters $\alpha, \beta, \gamma, \delta$ and ϵ are stored in the common block `common /kalinout/ wtkal(6)`, with the assignments shown in Table 2. The user is then free to calculate w for whatever combination of $F_2(0)$ and $F_3(0)$ is desired. In practice we set $\epsilon = 1$, since anomalous terms must vanish for $F_2(0) = F_3(0) = 0$. We also set $\delta = 0$, as the interference between Standard Model and anomalous amplitudes vanishes in the case of radiation from an electric dipole moment. These short cuts save substantial CPU time.

Common block entry	Weight parameter
wtkal(1)	not used here
wtkal(2)	ϵ
wtkal(3)	α
wtkal(4)	β
wtkal(5)	γ
wtkal(6)	δ

Table 2: Correspondence between entries in `kalinout` common block entries and weight parameters of eq. (2).

The code for calculation of the weight w is placed in the directory `korz_new/ttglib` in the files `ttg.f` and `ttgface.f`.

4 Demonstration programs

The demonstration program `DEMO2.f` for the run of KORALZ when our library is activated can be found in the directory `korz_new/february` and the output `DEMO2.out` in the directory `korz_new/february/prod1`. The Standard Model `DEMO.f` for KORALZ and its output `DEMO.out` are also included in the directories mentioned above. All these files, as well as the library itself, are archived together with KORALZ [6]. The maximum centre-of-mass energy allowed for the runs with anomalous $\tau\tau\gamma$ couplings is 200 GeV.

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